Dispatches

Baby Brain: Training Executive Control in Infancy

A recent study shows that a relatively short period of cognitive training can improve infants' ability to sustain and flexibly deploy attention. Thus, it appears important aspects of cognition can be modified using 'brain-training' techniques at an early age.

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The ability to control attention underpins human thought and action and is critical for early cognitive development. Children with poor attentional control, who are typically unable to stay on task, are at increased risk of developing behavioural and emotional difficulties and of educational failure. So, what can be done to help these children and how early can we intervene? This important question is addressed in a recent *Current Biology* paper from Wass *et al* [1].

First, some background. Attentional control, or executive control as it is sometimes called, allows us to think flexibly and creatively. It enables us to plan a series of thoughts or actions and hold relevant information in mind for short periods of time when carrying out mental tasks. It is crucial for the mastery of basic skills during the early years [2], for learning at school [3] and success later in life [4].

There is currently widespread excitement in the scientific community about a range of evidence-based computerised 'brain-training' programs that offer huge potential for improving executive control. This interest has been driven primarily by our increased understanding of the negative consequences of cognitive deficits [3] and the subsequent demand for targeted interventions. Technological advances that have facilitated the development of new interfaces for cognitive training have propelled this field over the past decade.

Approaches to cognitive training that have been most successful in delivering measureable gains are those that adopt intensive and sustained training paradigms [5–9]. Computerised training of working memory, a cognitive skill associated with attentional control [10], has been found to boost performance consistently on non-trained working memory tasks in children and adults [5–8]. Experiments involving executive control or attention training have also been carried out with children [11,12] and adults [13], with positive post-training effects on outcome measures closely related to the trained skills. Together, these studies establish that it is possible to modify cognitive control systems through direct training. Yet, given the desirability of early interventions [14], no study prior to Wass *et al.*'s [1] has successfully applied cognitive training to children younger than four years of age.

Wass *et al.* [1] used a ground-breaking and novel approach to train attentional control skills in 11 month olds. They assessed 42 infants on a series of tasks, either before and after cognitive training or before and after watching TV clips (Figure 1). Twenty-one children completed four training sessions over 15 days. The training tasks used in each session were designed to capture three core elements of executive control. They involved inhibiting distracting information on a computer screen, shifting and switching attention between targets on screen or holding in mind information that appeared on screen for short periods of time. All training tasks were implemented using eye-gaze contingent activation. This technique is typically used to reveal information about cognitive function through the study of eye movements in infants. In their study, Wass *et al.* [1] cleverly converted the methodology into a training tool. Infants looking behaviour was used as an index of on task behaviour in each of the training tasks and was reinforced accordingly. The remaining 21 infants formed an active control group. They viewed TV clips and still images on screen under the same experimental conditions as those who underwent training.

The results showed that, following training, infants were significantly better on tasks that involved cognitive control and sustained attention relative to the control group. Improvements on these tasks were related to the amount of time spent training. Significant improvements were also observed in infants' ability to disengage attention and there were trends towards improvements in spontaneous shifts in attention during free play post-training. These effects persisted three days after the final training session, indicative of short-term sustainability. There was no significant training-related effect for working memory.

These results demonstrate for the first time that it is possible to enhance cognitive function in infants. This is an important finding because early interventions that improve attentional control have the potential to prevent developmental delays and disorders. Moreover, these findings suggest that a relatively low dose regime (just four sessions) consisting of a range of training tasks is sufficient to boost performance, albeit moderately, in children of this age and that the effects are sustained over a short period of time. This stands in stark contrast to findings from studies with older individuals. For example, one large-scale internet study with adults demonstrated that a mixed bag of training activities, with low frequency of usage, was not effective [15]. Typically, more intensive paradigms that train a specific skill are needed to improve

Figure 1. Infant engaged in a training session, from Wass *et al.*'s [1] study.

and sustain performance in older children and adults (for example [5,6,9]). Perhaps these different patterns of responsiveness reflect age-related differences in the neural plasticity of the brain [16]. Are younger brains more amenable to training and therefore more responsive to lower intensity training regimes? Will the training effects in Wass *et al.*'s [1] study be sustained over the same period as they are in older children (three months [9] or six months [6]) and adults (three months [5]), or will they dissipate more rapidly?

So, will Wass *et al.*'s [1] study convince the sceptics that it is possible to implement 'brain training' with infants? It is certainly a bold first step, but it would be unwise to draw far-reaching conclusions at this stage. What it does show, however, consistent with an accumulating body of evidence from across the world, is that it is possible to enhance and modify cognitive function to some degree via direct training [5–8,10–12]. Whilst nobody is claiming that cognitive training is a panacea, it is difficult to deny that repeated practice improves performance both on trained and closely related cognitive tasks.

These exciting new developments hold the promise of remediating the cognitive deficits associated with a wide range of disorders, as well as boosting the cognitive reserves of the healthy, but scientists have a responsibility to exercise caution. To date, training gains are restricted to highly controlled experimental paradigms. As yet, very little is known or understood about how gains resulting from these training programs might (or more importantly, might not) transfer to meaningful improvements in an individual's daily life, or what the boundary conditions to positive training and transfer effects might be.

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Plant Sex Chromosomes: A Non-Degenerated Y?

Animal Y chromosomes have undergone chromosome-wide degeneration in response to a lack of recombination, and ancient Ys contain few functional genes. Recent research suggests that plant Y chromosomes may evolve differently and retain most of their ancestral genes.

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In many species with separate sexes, gender is determined by a pair of heteromorphic sex chromosomes. In animals, separate sexes are common, and sex chromosomes have evolved independently in a variety of species [1]. Animal sex chromosomes, particularly those of model organisms such as *Drosophila* and mammals, have been extensively studied and share several common features [2,3]. Gene densities of X chromosomes are similar to autosomes, while the male-limited Y chromosome is gene-poor, and consists mainly of repetitive junk DNA. Sex chromosomes originate from ordinary autosomes, and similar characteristics among independently evolved sex chromosomes suggest that similar evolutionary forces have shaped their evolution in different lineages [4,5]. In particular, the lack of recombination on the Y chromosome is thought to be directly responsible for its almost complete degeneration as observed in multiple old animal Ys. New research reported in a recent issue of *Current Biology* by Bergero *et al.* [6] and Chibalina *et al.* [7] suggests that plant sex chromosomes may follow a different evolutionary path.

Unlike animals, separate sexes are rare in plants [8,9]. Instead, male and female reproductive functions in most land plants are found within a single individual (i.e., plants are co-sexual). Only a small number of plant species (about 6%) have evolved separate sexes (dioecy), and dioecy shows a scattered taxonomic distribution [8,9]. This suggests that cosexuality is the ancestral condition in land plants. Dioecy has evolved recently and independently in plants, and is sometimes associated with the emergence of heteromorphic sex chromosomes [8,9].

The first step in the evolution of sex chromosomes is the acquisition of a sex-determining function on a former autosome (genetic sex determination).